Pacemaker Concepts and Terminology*

BAROUH V. BERKOVITS, E.E., Ing.
Associate in Surgery, Harvard Medical School, Boston, Mass., Associate in Electrophysiology, Miami University, Miami, Fla., Senior Research Scientist, Cedars-Sinai Medical Research Institute, Los Angeles, Calif., Consultant in Surgery, Peter Bent Brigham Hospital, Boston, Mass., Cardiovascular Research Manager, American Optical Corporation, Framingham, Mass.

Since the introduction of implantable cardiac pacing systems there have been marked advances in concept and design of the equipment available. Whereas intracardiac pacing is usually identified with A-V conduction disturbances, recently gained knowledge of cardiac physiology has shown that electrical stimulation of the heart can be beneficial in the treatment of many arrhythmias. It is important that the physician familiarize himself with the different modalities of pacing. The terminology used to describe the different concepts must be clear and precise so the physician can select the proper pacemaker concept for his patient without ambiguity.

Pacemakers can be divided into two categories, parasystolic and nonparasystolic. While parasystolic stimulation is independent of intrinsic activity; nonparasystolic stimulation is controlled by the intrinsic activity. The nonparasystolic pacemakers can be either inhibited, in which intrinsic signals suppress stimulation, or triggered, in which intrinsic signals induce stimulation. According to the site of stimulation the pacemakers can be atrial, ventricular, or A-V sequential. Pacemaker types in present use are

1. Parasystolic (Continuous)
   a. Fixed or set rate atrial pacer
   b. Fixed or set rate ventricular pacer
   c. Fixed or set rate A-V sequential pacer

2. Triggered (Synchronous)
   a. P-wave triggered ventricular pacer
   b. QRS triggered ventricular pacer

3. Inhibited (Demand)
   a. P-wave inhibited atrial pacer
   b. QRS inhibited ventricular pacer
   c. QRS inhibited A-V sequential (Bifocal)

The parasystolic pacemakers (continuous fixed rate) may be used to stimulate the atria, ventricles, or stimulate both the atria and ventricles with a preset sequential delay. In the presence of natural beats the modality of stimulation is not affected and it competes with the intrinsic activity. The stimuli falling in the absolute refractory period will induce no response, but those falling in the vulnerable interval may induce repetitive response or even fibrillation.

Figure 1 illustrates the differences between the various modalities of nonparasystolic pacing.

Characteristics of P-wave triggered ventricular pacing are:
1. The P waves trigger the pacemaker, which in turn stimulates the ventricles synchronously after a preset delay of 120 milliseconds.
2. This pacer usually has a refractory period of 500 milliseconds (measured from the beginning of the P wave) which prevents the pacemaker from following atrial tachycardia or fibrillation.
3. When natural P waves do not appear for a preset interval (1.04 sec.) the P-wave triggered pacemaker escapes. This escape mechanism protects against asystole when there are no P waves present. Thus, the pacemaker works either in synchronous or escape modality.

Characteristics of QRS triggered ventricular pacing are:
1. The QRS complexes trigger the pacemaker, which in turn stimulates the ventricles during its absolute refractory period. In the latest models, this synchronized stimulation is delivered immediately after the detection of the ventricular endocardial signal.
2. The pacemaker has a refractory period of 400 to 500 milliseconds. This built-in refractory period is designed to protect the unit from running at fast rates. A long refractory time may prevent the recognition of premature beats and thus causes escape stimulation competing with these premature beats. Competition with premature beats is even more hazardous than with the normal beats.
3. When natural QRS complexes do not appear for a preset interval (840 milliseconds), pacemaker escapes occur to protect against asystole.

Contrary to the triggered pacemakers, the demand pacemakers work only in escape mode. In the presence of a faster natural rhythm, the demand pacemaker is dormant and no stimuli are delivered to the heart.

Stimuli are delivered only if the natural beat fails to occur for a preselected escape interval. Consequently, the heart is stimulated only when needed (on demand), and competitive rhythms or stimulation during the vulnerable phase are thus avoided.

Figure 2 shows how the ventricular demand or

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Fig 1—Differences between the various modalities of non-parasystolic pacing.

Fig 2—Actual workings of the ventricular demand or inhibited pacemaker.

Fig 3—Schematic illustration of the different modalities of pacing.
Fig 4—Basic construction of the Bifocal demand pacemaker compared to the conventional demand unit.

Fig 5—The Bifocal demand pacemaker facilitating the natural depolarization sequence without competing with spontaneous ventricular activity.
PACEMAKER CONCEPTS AND TERMINOLOGY

**BIFOCAL DEMAND PACEMAKER**

**WORKING IN ATRIAL MODE; OCCASIONAL PVC S & COMPENSATORY PAUSE IN ATRIA**

Fig 6—Bifocal pacemaker placed in a patient with sinus bradycardia and premature ventricular contraction.

**BIFOCAL DEMAND PACEMAKER**

**ON-MAGNET-OFF TESTING RESPONSE OF VENTRICULAR STIMULATION**

Fig 7—Bifocal pacemaker placed in a patient with first degree A-V block.

**BIFOCAL DEMAND PACEMAKER**

inhibited pacemaker actually works, imitating the natural escape rhythm of an automatic fiber. The upper part of the tracing demonstrates how the automatic fiber works and how the threshold potential is reached during phase four depolarization so that these fibers can fire by themselves and produce escape beats. The bottom portion of the figure demonstrates how the pacemaker is controlled by a capacitor that restores its charge with each detected beat. In short, each time a depolarization signal is detected the pacemaker is reset and the timing cycle is started again. When the capacitor's charge reaches the critical level because of the prolonged interval, it permits escape and a stimulus is delivered to the ventricle. The pacemaker actually delivers its stimulation in the same fashion as an automatic fiber.

Figure 3 demonstrates schematically the different modalities of pacing. As shown, Bifocal pacing is similar to A-V sequential pacing, except that it is on demand and it is inhibited and reset by endocardial ventricular depolarizations. The Bifocal demand pacemaker adapts its modality of stimulation to the patient's need. It combines the advantages of atrial, A-V sequential, and demand stimulation. It may remain dormant, it may stimulate only the atria, or it may stimulate both the atria and the ventricles with a preset sequential A-V interval. The Bifocal demand pacemaker does not compete with the spontaneous ventricular activity and it has no significant refractory time.

Figure 4 illustrates the basic construction of the Bifocal demand pacemaker and compares it to the conventional demand unit. In conventional demand pacing the ventricular signal detected by a QRS detector will control the timing circuit of the ventricular demand stimulator. A magnetic switch is incorporated in these pacers for evaluation of pacemaker function by preventing inhibition and thus converting the unit to a fixed-rate mode. When testing the pacemaker, the rate produced by the magnetic switch is independent of the patient's physiological condition and should be used to determine the condition of the batteries. It is important that during each outpatient visit the demand pacemaker be checked by applying a magnet and this rate recorded for control. Conceptually, the Bifocal pacemaker is comparable to the conventional demand pacemaker except that atrial stimulation controlled by the same QRS detector has been added.

Two functions of the Bifocal pacemaker are demonstrated in Figs. 5, 6, and 7. Figure 6 shows a Bifocal pacemaker in a patient with sinus bradycardia and premature ventricular contractions. It can be observed that the atrial pacemaker compensates for the premature ventricular beats. Figure 7 shows a Bifocal pacemaker in a patient with first-degree A-V block. The sequential interval of the pacemaker was
similar to the patient's own conducted A-V interval. Therefore, the different degrees of fusion and changes in morphology can be observed.

Figure 8 depicts the testing of a Bifocal pacemaker with a magnet, similar to the ventricular demand pacemaker. The measurement of the interval during a magnet-induced fixed-rate mode should be recorded in order to follow the pacemaker function and determine battery condition. A change greater than 10 percent indicates battery failure.

During the past 18 months we have implanted 60 Bifocal pacers with encouraging results. In the early stages, the basic indication for implantation of Bifocal pacers was to improve cardiac output. Recently, Bifocal pacemakers have also been used for patients with sick sinus syndrome—atrial brady-tachyrythmias. In a number of patients, we have found that 2 to 3 months after implantation, drugs could be progressively discontinued, and that the atrial stimulation not only protected against the bradycardia but also suppressed the episodes of tachycardia.

Pacing therapy has undergone marked evolution during its relatively brief existence. Further developments in concept, clinical applicability and technical areas are forthcoming. The physician has the obligation to understand the various pacing modalities and to select the most suitable concept of pacing for each particular disorder (Table I)

Author's note. "BIFOCAL" is a trademark of the American Optical Corporation for the QRS inhibited A-V sequential pacemaker

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<tr>
<th>TABLE I</th>
<th>THREE DIFFERENT MODALITIES OF A-V PACING</th>
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<tr>
<td>P-wave Triggered</td>
<td>A-V Sequential (Continuous)</td>
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<tr>
<td>For Normal Atrial Activity With A-V Block</td>
<td>For Atrial Bradycardia With A-V Block</td>
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<tr>
<td>Monitors P-waves</td>
<td>No monitoring</td>
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<tr>
<td>P-waves Control Ventricular Stimulation No Atrial Stimulation Available</td>
<td>Continuous Atrial and Ventricular Stimulation</td>
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<tr>
<td>Stimulation is Delivered to the Ventricles Continuously</td>
<td>Stimulation is Delivered Both to the Atria and Ventricles Continuously</td>
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